Results: The mean age was 65.3 years (s.d. 9.0), 50% were male, mean BMI was 29.7 kg m^{-2} (s.d. 4.5); 65% had radiographic OA. Those with a more varus alignment have a greater medial tBVF, Tb.N, Tb.Th, and lower Tb.Sp; they also have greater medial tibial paBMD and medial:lateral paBMD ratio. Those with greater femoral neck BMD have a greater varus alignment, an association present in those with and without radiographic OA.

Table: Correlations of corrected static alignment with trabecular morphometry, BMD, and demographics

	All participants (N = 320)		KL < 2 (N = 103)		KL > 2 (N = 181)	
	r	p	r	p	r	p
Medial tibial tBVF	0.27	<0.0001	0.17	0.09	0.26	0.0005
Medial tibial Tb.N	0.30	<0.0001	0.26	0.0092	0.28	0.0002
Medial tibial Tb.Th	0.20	0.0004	0.04	0.69	0.20	0.0005
Medial tibial Tb.Sp	−0.22	<0.0001	−0.19	0.05	−0.22	0.0033
Medial:Lateral paBMD ratio	0.44	<0.0001	0.33	0.0007	0.48	<0.0001
Medial tibial paBMD	0.33	<0.0001	0.28	0.0037	0.33	<0.0001
Femoral Neck BMD	0.18	0.001	0.19	0.06	0.18	0.02
Age	−0.04	0.45	−0.11	0.26	−0.04	0.64
BMI	−0.02	0.70	−0.06	0.54	−0.09	0.23

Conclusions: Static knee alignment is strongly associated with periarticular trabecular morphometry and periarticular BMD. Knees with greater varus malalignment have morphometry consistent with trabecular bone compression. These associations are stronger in those with as compared to without radiographic evidence of OA. These findings suggest that modification of static alignment could alter periarticular bone in knee OA.

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RISK FACTORS FOR REVISION OF PRIMARY TOTAL HIP REPLACEMENT: A NATIONAL CASE CONTROL STUDY WITH TWELVE YEAR FOLLOW-UP

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Purpose: Over 50,000 revision total hip replacements (THRs) are done annually in the US to manage failed primary THR. There have been no population-based studies of risk factors of failure of primary THR leading to revision. We performed a nested case control study of risk factors for revision following primary THR in the US Medicare population, which includes essentially all US residents ≥5 years old.

Methods: The sample included Medicare beneficiaries from 29 US states who underwent primary THR from July 1995 through June 1996. The patients were followed with Medicare claims data through 2008. We identified as potential cases patients with ICD-9 codes indicating a revision THR during the follow-up period. Each of these patients was matched with one control who resided in the same state and was alive and not revised at the time the case had revision. We requested hospital records corresponding to the primary THR for cases and controls and the revision THR for cases. The records were abstracted to document potential risk factors present at the time of the primary THR including demographic, clinical and surgical/technical features. The records were also used to confirm that putative cases indeed had revision on the index side. Bivariate and multivariate conditional logistic regression models were used to examine associations between potential preoperative risk factors and revision status.

Results: Complete sets of medical records were obtained for 836 cases of bona fide revision THR and an equal number of matched controls. There were no statistically significant or clinically important differences in age, sex and comorbidity between patients whose medical records were retrieved and those whose records were not retrieved. The final multivariate conditional logistic regression model (see Table) shows that a higher odds of revision was associated with age ≤ 75, body mass index (BMI) >30, use of a cemented femoral component, prior contralateral THR, other orthopedic surgery and living with others at the time of primary THR. Greater height, weight and BMI were essentially interchangeable in the model; each was similarly predictive of revision risk.

Conclusions: This first US population-based nested case control study of risk factors for revision of primary THR showed that younger and heavier patients and those receiving a cemented femoral component are at higher risk for revision over twelve year follow-up. The associations of contralateral THR and other orthopedic surgery with revision may reflect more frequent contact between these patients and orthopedic surgeons. The effect of living with others may represent increased social support, facilitating elective surgery. Further research is needed to determine whether these findings extend to younger THR recipients.

Table: Associations between preoperative factors and risk of revision THR in US Medicare recipients

Factor	Adjusted OR (95% CI)
Age ≤ 75	1.6 (1.2, 1.9)
BMI > 30	1.5 (1.1, 1.9)
Cemented femur	1.4 (1.1, 1.9)
Living with others	1.2 (1.0, 1.6)
Prior contralateral THR	1.4 (1.1, 1.8)
Other orthopedic surgery	1.4 (1.1, 1.8)

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SAGITTAL PLANE HIP MOTION DURING GAIT AND FUNCTION AND DISABILITY IN KNEE OSTEOARTHRITIS

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Purpose: Previous studies have established that sagittal plane range of motion at the knee during gait is associated with physical function in knee osteoarthritis (OA) (Maly 2006). The impact of knee OA on sagittal plane knee motion may lead to a greater reliance upon the hip in daily activities. Even when both knees are healthy, the hips play a critical role in walking, turning, maintaining balance, ascending and descending stairs, rising from a seated position, dressing, and getting in and out of a car. When knees are osteoarthritic, the compensatory role of the hip may be considerable. In persons with knee OA, reduced dynamic sagittal plane motion during gait at the hip may be a result of shortness of the two joint hip flexors and/or the tensor fascia lata-iliotibial band complex. We hypothesized that reduced sagittal plane range of motion during gait at the hip is associated with worse function and greater disability in persons with knee OA.

Methods: We studied 250 persons with knee OA (defined by osteophyte presence in at least one knee). Quantitative gait analysis was performed at the participant's self-selected normal walking speed to calculate kinematic and kinetic data for both the hip and the knee. Function was evaluated using: the WOMAC function scale; the Late Life Function Instrument (LL-FI), basic and advanced lower extremity function scales; and 20 m walk time. Disability was measured using: the Late Life Disability Instrument (LL-DI), activity frequency and activity limitation scales. To evaluate the relationship between sagittal motion during gait (independent variable) and function or disability (dependent variables), linear regression models were used (analyzing the data from the limb with less sagittal motion). Results are reported as regression coefficients (slopes) and associated 95% confidence intervals (95% CIs), separately for each dynamic range of motion variable, adjusted for age, gender, and BMI.

Table: Dynamic sagittal plane hip and knee motion and measures of function and disability

	WOMAC	20 m walk	LL-FI, LE function		LL-DI, activity	
	function scale	time	Basic	Advanced	Frequency	Limitation
Sagittal *hip* motion (°)	**−2.37 (−3.60, −1.15)**	**−1.53 (−1.77, −1.29)**	**3.04 (1.61, 4.47)**	**2.86 (1.54, 4.17)**	**1.37 (0.64, 2.11)**	**2.35 (0.95, 3.74)**
Sagittal *knee* motion (°)	**−1.75 (−3.06, −0.44)**	**−0.89 (−1.20, −0.58)**	1.49 (−0.06, 3.05)	**1.47 (0.02, 2.93)**	−0.50 (−1.30, 0.31)	1.12 (−0.40, 2.63)

Results: 250 participants had a mean age of 64.8 (SD 10.2), BMI 28.6 (5.6), and 189 (76%) were women. Mean (SD) sagittal hip motion during the entire gait cycle was 43.1° (5.6), and for the knee was 60.9° (5.5). The table shows the adjusted coefficients per 5° (95% CI), with significant values bolded. Dynamic hip motion was significantly associated with function by self-report, performance function, and both measures of disability; dynamic knee motion was associated with the function measures but not these measures of disability.

Conclusions: Sagittal motion at the hip during gait was consistently associated with measures of function and disability, supporting a compensatory role played by the hip in the setting of knee OA.

Longitudinal studies will help to elucidate whether dynamic sagittal motion at the hip during gait should be a rehabilitative target (e.g. addressing muscle length deficits through stretching of the hip flexors and concomitant strengthening of hip extensors, gait training) to potentially enhance outcome for persons with knee OA.

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DIAGNOSIS OF EARLY OSTEOARTHRITIS BY KNEE JOINT CONGRUITY QUANTIFIED AUTOMATICALLY FROM MRI

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Purpose: Biomechanical factors play a vital role in the pathogenesis of OA. Congruity may be an important factor contributing to the initiation and progression of OA in the synovial joints. We investigated whether medial tibio-femoral congruity computed automatically from magnetic resonance imaging (MRI) could be appropriate as a diagnostic marker of early Osteoarthritis (OA).

Methods: The study population consisted of 159 subjects with 48% female. The age and BMI of the subjects were 21–82 years and 18–38 (kg/m2) respectively. Radiographs were acquired to grade the severity of OA by the Kellgren & Lawrence index (KL). The MRI scans were acquired using an Esoate C-span scanner at 0.18T (400 flip angle, 50 ms repetition time and 16 ms echo time). The medial tibio-femoral cartilage compartments were segmented automatically using a voxel classification approach.

The Contact area (CA) of the tibio-femoral compartment was estimated by employing the voxel width (0.7 mm) as threshold. Further, in the contact region, the point-by-point congruity (dimensionless number) was quantified over CA as the inverse mean of the distance between local normal vectors scaled by signed curvature along local principal knee motion. The precision of congruity was quantified on 31 scan-rescan pairs as Root mean squared coefficient of variation (RMS CV). The ability of congruity to separate healthy (KL 0) from OA was quantified as area under ROC curve (AUC). The population was randomly split into train subpopulation and validation subpopulation. The parameters in the quantification (curvature scale and iteration number in mean curvature flow) were optimized for best AUC on train subpopulation and then tested on validation subpopulation. The process was repeated 100 times and the resulting median scores on the validation subpopulation were reported.

Results: The precision of the congruity measure was 7.7%. The congruity map for a healthy knee is shown in Figure 1 (red is good and blue/green is bad).

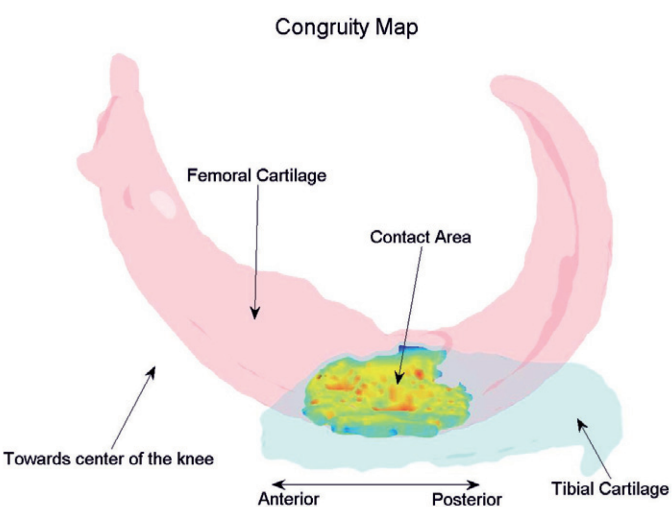

Fig. 1.

The ability of the congruity marker to separate healthy (KL 0) and early OA (KL 1) was significant with AUC 0.62 ($p = 0.004$) (Figure 2). The ability of the congruity to separate KL 0 and KL > 0 was significant with AUC 0.69 ($p < 0.0001$) and the corresponding cross-sectional separation is also shown in Figure 2.

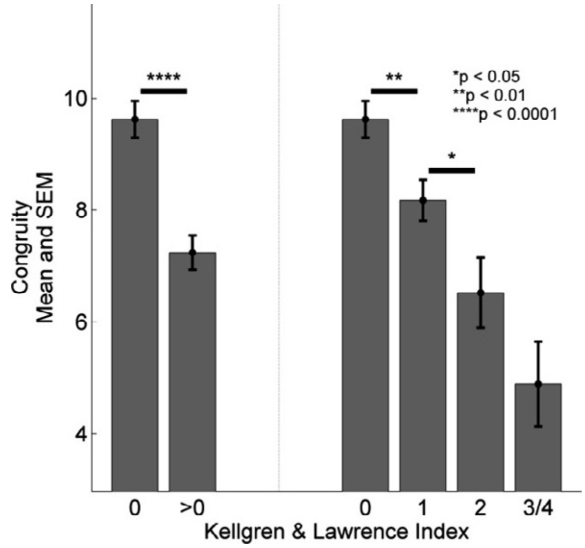

Fig. 2.

Conclusions: We present a method to quantify the medial tibio-femoral joint congruity automatically from MRI. From the quantifications, we conclude that the congruity marker may even separate healthy from early OA. In general, the healthy knees were more congruent than OA knees in the medial tibio-femoral compartment.

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MRI-BASED 3D BONE SHAPE PREDICTS INCIDENT KNEE OA 12-MONTHS PRIOR TO ITS ONSET

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Purpose: There is a need to develop imaging biomarkers for OA that are more sensitive than the current standard of knee x-rays. Since mechanical factors play a central role in knee OA development and bone adapts to its mechanical influences, MRI-based 3D bone shape may be a sensitive marker of knee OA onset. We have previously demonstrated that 3D bone shape changes tracked *concurrently* with disease onset. We evaluate here the ability of knee MRI-based 3D bone shape to *predict incidence* of radiographic knee OA 12 months before its onset.

Methods: The OAI is a longitudinal observational cohort of persons with or at high risk of knee OA in which bilateral posterioranterior weight-bearing knee x-rays and 3T MRIs were obtained annually. Knee x-rays were read for Kellgren and Lawrence (KL) grade by musculoskeletal radiologists. Incident x-ray OA was defined as $KL \geq 2$ identified in a follow-up study visit (12, 24, or 36 mo) among knees that were $KL < 2$ at baseline. From among the x-rays read to date, we identified 86 knees that developed incident OA over any of the follow-up visits. Each case was matched to 2 control knees that remained free of OA at the same clinic visit (index visit) as when the case knee developed incident OA, and with the same baseline KL grade.

We applied a statistical model of the femur and tibia bone surfaces developed from an unrelated dataset that best distinguished established OA vs. non-OA shapes to each knee MRI (DESS-we sequence) (blinded to case status) from each clinic visit (baseline, 12, 24, and 36 mo). This resulted in a standardized grid of points fitted to the femur and tibia within each image. Linear discriminant analysis was used to identify vectors for the femur, tibia, and both bones combined that best classified the groups as having incident OA or not at that time point. For each image, this method produces a single value of the distance along the vector, which is scaled such that the mean non-OA shape is −1 and the mean OA shape is +1. We examined the ability of those 3D bone shape vectors to predict the occurrence of incident radiographic OA 12 months later in our matched case-control sample using conditional logistic regression. The 3D bone shape vectors were assessed as continuous variables, as well as categorized into tertiles. We repeated analyses limited to just those case and control knees that were KL=0 at baseline to disentangle early OA changes (at KL=1) being reflected in the 3D bone shape.